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Flower Promotion in Black Spruce Seedlings Using Gibberellins

J. Peter Hall

Information Report N-X-252
Newfoundland Forestry Centre



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by J. Peter Hall

INFORMATION REPORT N-X-252
1986

CANADIAN FORESTRY SERVICE
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ISSN No. 0704-7657

CAT. No. Fo46-15/252E

ISBN No. 0-662-15114-3

Copies of this report are available at no charge from:

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ABSTRACT

Twenty-year old black spruce seedlings were sprayed with the gibberellins GA4/7, GA₉ and the auxin NAA in early July and August. The July application resulted in the formation of many more flowers than did the August one. More male than female flowers were produced. Female flowering was induced only when trees were sprayed with GA4/7 at 200 and 800 mg/l and no difference was found between the two concentrations. Male flowering was induced when GA4/7 was sprayed at 800 mg/l and when coupled with GA₉ and NAA. Treatment in August with GA4/7 + NAA also promoted flowering.

Effects of treatments persisted to some degree in the second year following treatment. Flowering and tree height were not related in the first year after treatment but were related two and three years after treatment. Seed yields were reduced in the treated trees, compared to the controls, one year after treatment. The effects did not persist into the second year. Treatment did not affect terminal shoot growth. Further studies are suggested modifying concentrations and application dates.

RÉSUMÉ

Des épinettes noires, âgées de 20 ans, issues de semis ont été arrosées avec les gibbérellines GA4/7 et GA₉ et une auxine, l'acide naphtyl-acétique, au début de juillet et en août. L'épandage effectué en juillet a entraîné la formation de beaucoup plus de fleurs que celui d'août. Également, plus de fleurs mâles que de femelles ont été produites. Pour les fleurs femelles, la floraison a été induite seulement chez les arbres arrosés avec le produit GA4/7 aux doses de 200 et de 800 mg/L, et aucune différence n'a été observée entre les deux concentrations. Dans le cas des fleurs mâles, la floraison a été induite par le produit GA4/7 quand il était épandu à la dose de 800 mg/L et quand il était mélangé avec le GA₉ et l'auxine. Le traitement effectué en août avec un mélange du GA4/7 et de l'auxine a également favorisé la floraison.

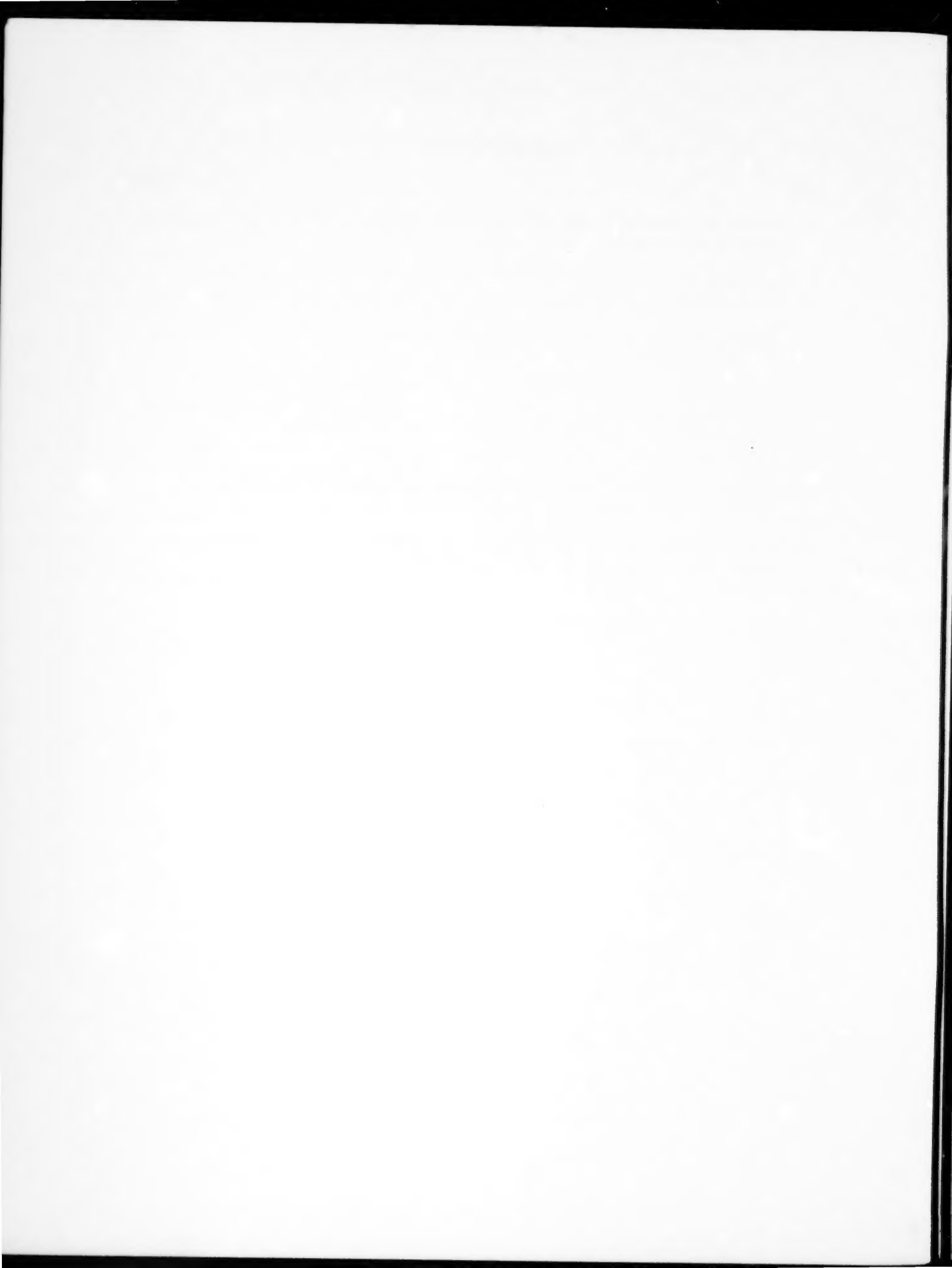
Les effets des traitements ont persisté, jusqu'à un certain point, dans la deuxième année après le traitement. On n'a pas observé de rapport entre la floraison et la hauteur des arbres au cours de la première année, mais un tel rapport a été observé deux ans et trois ans après le traitement. Un an après le traitement, la production de graines était réduite chez les arbres traités, par comparaison aux arbres témoins. Les effets n'ont pas persisté dans la deuxième année. Les traitements n'ont pas influé sur l'accroissement de la pousse terminale. On suggère la réalisation d'autres études à des concentrations et à des dates différentes.

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INTRODUCTION

Current reforestation programs in Canada require large amounts of conifer seed for seedlings and for direct seeding. Demands are increasing to the point where seed is the limiting factor (Morgenstern and Carlson 1979). Genetically improved seed from seed orchards is in even greater demand but despite high levels of investment in seed orchards flowering levels are low. Seed production is often erratic and the genotype of 'superior seed' varies widely from year to year. For example in a seed orchard of loblolly pine (Pinus taeda L.) it was found that 22% of the clones produced 62-76% of the seed for three successive years (Schmidtling 1983). Concentration of seed production on so few clones reduces the genetic diversity. Erratic flowering causes delays and interruptions in research programs. If early and consistent flowering could be assured then the efficiency of breeding programs would be increased.

The objectives of this study were to determine if flowering levels could be enhanced by applying the gibberellins GA₄/7, GA₉ and the auxin Naphthaleneacetic acid (NAA) on 20-year old black spruce seedlings.

In the past the flowering levels of conifers have been altered by cultural methods which include: fertilization, stem girdling, root-pruning, water stress and manipulation of branch angle. Results, however, have been inconsistent and this has focused attention on other approaches. If it were assumed that flowering resulted from a succession

of developmental stages which were affected by the balance of endogenous hormones then the manipulation of these balances might increase the production of floral buds. It has been observed that levels of endogenous gibberellins varied during the cultural treatments which eventually resulted in increased levels of flowering in conifers (Kamienska et al. 1973). Stimulation of flowering in Cryptomeria with gibberellins was reported by Kato et al. (1958). Dunberg (1974) showed that clones of Norway Spruce (Picea abies (L.) Karst.) that consistently flowered had higher endogenous levels of gibberellin-like substances at the time of flower bud initiation than clones that produced few or no flowers.

The gibberellins used to promote flowering have had variable results depending upon the substances used. Varying responses have also been reported for species in the Taxodiaceae, Cupressaceae and Pinaceae families. Application of GA_3 to species in the Taxodiaceae and Cupressaceae has stimulated flowering and the treatment is used on an operational basis (Kato et al. 1973). In Pinaceae, enhanced flowering has occurred after treatment with less-polar gibberellins such as a mixture of GA_4 and GA_7 (Pharis and Ross 1976, Pharis et al. 1976, Pharis 1979). Application of the polar GA_3 on loblolly pine and European Larch (Larix decidua Mill.) and Japanese Larch (L. kaempferi (Lam.) Carr.) were ineffective in promoting flowering (Greenwood 1982, Hall 1977). This is consistent with results in a study of cultural methods used to promote flowering in Norway spruce where the levels of less-polar gibberellins increased and remained high after treatment (Chalupka et al. 1982).

Methods of flower promotion in the Pinaceae have centered on the commercially valuable conifers particularly Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), Scots pine (P. sylvestris L.) Norway Spruce and the southeastern hard pine group (Pharis and Ross 1984). Studies have also been conducted on boreal species, jack pine (P. banksiana Lamb.) (Cecich 1981, 1983), and white spruce (P. glauca (Moench) Voss) (Marquard and Hanover 1984a, 1984b, 1985; Hare 1984; Cecich 1985). The other major boreal conifer, black spruce (P. mariana (Mill.) B.S.P.) has received little attention. It is, however, the major reforestation species in Newfoundland and tree improvement programs concentrate on this species (Hall 1981). As a part of these programs a study of flower promotion was initiated in black spruce.

The most frequently tested gibberellin has been a GA4/7 mixture applied as a foliar spray or injected into the pith or cambium (Pharis and Ross 1984). The effects of GA4/7 have been enhanced by its combination with GA₃ and/or the auxin Naphthaleneacetic acid (NAA) Dunberg 1980, Ross et al. 1980). Other researchers have also reported the efficacy of inclusion of a surfactant to improve penetration of growth hormone into the tissues (Pharis and Ross 1976; Cecich 1983, 1985; Hare 1984). The concentration of growth hormone also affects results. A direct relationship between concentration and flowering level was reported in jack pine (Cecich 1983), white spruce (Marquard and Hanover 1984b, 1985), Sitka spruce (P. sitchensis (Bong.) Carr.) (Thompsett and Fletcher 1979; Philipson 1985), Douglas fir (Ross 1983) and western hemlock (Tsuga heterophylla (Raf.) Sarg.) (Ross et al. 1981). Various times

of application have also been tested; application on the developing shoots in Norway spruce (Luukkanen 1980), before cone-bud differentiation in western hemlock (Tsuga heterophylla (Raf.) Sarg.) (Ross et al. 1981), early to late in shoot development in loblolly pine (Schmidtling 1983) and two weeks before the cessation of shoot growth in white spruce (Marquard and Hanover 1984b). Marquard and Hanover (1984b) also report that treatment of shoots which are 15 to 75% elongated particularly enhances female flowering. Chalupka (1984) reported differential effects on male and female flowering in Scots pine; application in May-June enhanced male flowering while application in July-August enhanced female flowering. Finally, growth hormones have been applied on both grafts and seedlings with similar results (Ross et al. 1980).

The effects of various treatments on seed quality and on subsequent levels of flowering have also been investigated. No deleterious effects on seed quantity have been found in Douglas-fir (Puritch et al. 1979; Ross et al. 1980), Sitka spruce (Thompsett et al. 1980), and western hemlock (Ross et al. 1981). Occasional reductions in numbers of viable seed per cone were more than compensated for by the increased numbers of cones. Enhanced flower production has been observed to occur in years subsequent to treatment in Scots pine (Luukkanen and Johansson 1980b), white spruce (Cecich 1985) and in Japanese and European larch (Bonnet-Masimbert 1982). Hormone and cultural treatments have been shown to have synergistic effects (Pharis and Ross 1984).

MATERIAL AND METHODS

The study area is located in east-central Newfoundland, lat. 48°42', long. 54°33', at an elevation of 110 m. In 1978 the area was thinned for use as a seed production area; study trees were open-grown and received full sunlight. The study trees were part of a natural black spruce stand which originated after wildfire in 1961. The trees selected had not previously produced female flowers but may have produced male flowers. The trees averaged three metres in height.

Gibberellin A4/7 was used in all treatments¹. Because of the reported enhancement effects of GA₉ and NAA these two were also tested. The following hormonal treatments and concentrations were tested:

1. Control - 60% Ethanol
2. GA4/7 @ 200 mg/l
3. GA4/7 @ 800 mg/l
4. GA4/7 @ 200 mg/l + GA₉ @ 10 mg/l
5. GA4/7 @ 200 mg/l + NAA @ 100 mg/l

Growth hormones were dissolved in absolute ethanol and stock solutions were made up in 60% ethanol. Then 1 ml/l of the surfactant "Aromox C12W"² was added to the ethanol solution. The substances were

¹GA/7 - 45.4%, GA4/7 - 92.5%; GA₉ supplied courtesy of ICI Ltd., Plant Protection Division.

²Aromox C12W supplied courtesy of Arma Chemicals Limited, 100 University Ave., Toronto, Ont.

applied as a foliar spray with each tree receiving about 400 ml of solution. Effects of hormonal treatments have often been enhanced by cultural treatments, but since the trees were in an isolated locale, neither girdling nor drought stress nor other cultural treatment was practicable.

Two application dates were tested; on 7 July 1982 when shoot elongation was about half complete, and on 4 August when shoot growth was nearly complete. Each of the five treatments was applied to four randomly selected trees on each date for a total of 40 trees. The statistical design was a randomized complete block (Steel and Torrie 1960).

The height of the sample trees was measured before and after treatment to see if there was any relationship between flowering levels and tree height. A direct relationship between height and flowering has been reported in black spruce (Simpson and Powell 1981). Numbers of male and female flowers were counted on each tree in June 1983. Cones were collected in October 1983 to assess effects of treatments on seed quantity and quality. Unfortunately a severe frost in late June killed most female flowers and only partial data are available. Male and female flowers were also counted in June 1984 and the seed yield was assessed. The number of cones was also determined in 1985.

The results of the treatments were assessed on the basis of numbers of flowers per tree and analysis of variance performed according to Steel and Torrie (1960). The data were transformed by the arcsin method also used by Bonnet-Masimbert (1982). The relationship between

flowering and tree height was described using regression analysis (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Number of Flowers

Application of hormones resulted in greater numbers of flowers in July over August and generally greater numbers of males than females (Table 1). Although differences among treatments were large, they were not statistically different because of wide tree-to-tree variation (Table 2). Wide tree-to-tree variation in flowering levels has been reported elsewhere in black spruce (Simpson and Powell 1981), and in Norway spruce (Dunberg 1980). Only the differences between treatment dates were statistically significant and this was the case for both male and female flowers.

Promotion of flowering using GA4/7 has also been reported in Douglas-fir (Ross 1979; Puritch et al. 1979; Ross et al. 1980; Pharis et al. 1980); in European and Japanese larch (Katsuta et al. 1981; Bonnet-Masimbert 1982); in jack pine (Cecich 1981, 1983); in Norway spruce (Luukkanen 1979; Luukkanen and Johansson 1980a, 1980b; Dunberg 1980); and in white spruce (Hare 1984; Marquard and Hanover 1984a, 1984b). The results in black spruce are thus consistent with the literature. No increase in female flowering resulted from the August spraying indicating that the correct time for female flower promotion is earlier than for males. Marquard and Hanover (1984b) also found female flowering

Table 1. Number of flowers (mean and range) on black spruce one year following treatment.

Growth substance	Concentration mg/l	Number of Flowers							
		Male				Female			
		July		August		July		August	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Control	-	1.8	0-7	1.8	0-7	1.0	0-4	7.8	0-31
GA4/7	200	7.2	1-16	2.2	0-9	27.8	0-67	0	-
GA4/7	800	118.2	0-261	0	-	28.2	0-79	0.2	0-1
GA4/7 GA ₉	200 10	22.5	3-74	2.8	0-7	2.0	0-4	0	-
GA4/7 NAA	200 100	43.8	2-88	47.2	0-155	8.0	0-20	2.5	0-10

Table 2. Analysis of variance of numbers of flowers one, two and three years following treatment.

Source of variance	dF	F ratio year 1		F ratio year 2		F ratio year 3
		Male	Female	Male	Female	Female ¹
Replicates	3	.25 n.s.	.77 ² n.s.	.70 n.s.	1.89 n.s.	1.85 n.s.
Hormone treatments	4	3.25 n.s.	.79 n.s.	.61 n.s.	.99 n.s.	.89 n.s.
Error (a)	12					
Application dates	1	4.73*	14.12***	2.07 n.s.	1.56 n.s.	2.76 n.s.
Hormone x dates int.	4	1.87 n.s.	9.32***	6.35***	.52 n.s.	.90 n.s.
Error (b)	15					
Total	39					

¹Data on male flowering not collected in year 3.

²n.s. no significant difference at P = 0.95, *significant at P = 0.95, **significant at P = 0.99, ***significant at P = 0.995.

to be promoted by early flowering treatment (later treatments were ineffective) and early application best for male flowering.

Differential effects on male and female flowering have also been widely reported (Bonnet-Masimbert 1982; Marquard and Hanover 1984b; Chalupka 1984). The black spruce trees were old enough to produce flowers of both sexes so the normal early dominance of female flowering in young trees does not account for differences between sexes in flowering levels in the sample trees.

Comparing the various treatments, female flowering was promoted only by GA4/7 and there was no response attributable to concentrations. Philipson (1985) also found no dosage-related response in Sitka spruce but contrary results were reported by Thompsett and Fletcher (1979). The reported synergistic effects of GA₃ and/or NAA (Dunberg 1980; Pharis and Ross 1984) were not evident in black spruce. Male flowering was enhanced by GA4/7 at the higher concentration and when NAA was used. It is possible that the GA4/7 triggers female flowering at a low concentration and male flowering at a higher concentration. If this differential response can be demonstrated then it could be exploited in a breeding program. Use of the auxin NAA in this study promoted male but not female flowering. Elsewhere it has been shown to have a neutral effect (Marquard and Hanover 1985) and a stimulative effect (Pharis et al. 1986) in white spruce. It has been reported to stimulate flowering in loblolly pine and to inhibit flowering in slash pine (P. elliotii Engelm.) and longleaf pine (P. palustris Mill.) (Hare 1984). In Japanese larch NAA has been found to inhibit both male and female flowering (Hall 1977) but the

opposite effect was reported for Douglas-fir and Scots pine (Ross 1976; Ross et al. 1980; Luukkanen 1980). Results for black spruce most closely resemble the effects in larch. It is possible that the NAA blocks the gibberellin effect or actively inhibits flowering itself.

Carry-over Effects

Chalupka et al. (1982) reported that levels of endogenous gibberellins increased at the time of flower induction and remained high. Increased flowering in years subsequent to GA4/7 application was reported to occur in Scots pine (Luukkanen and Johansson 1980b) and in Japanese and European larch (Bonnet-Masimbert 1982). In this study nearly all trees - treated and control - flowered in the second year (Table 3). The difference between application times was significant in year two but differences were not significant in year three (Table 2). When comparing control and treated trees it appears that there may even have been some inhibition of flowering on treated trees.

The increase in male flowering in year two could be attributed, in part, to the gradual increase in the male flowering zone as new shoots are formed and as females are initiated on new shoots which have not been treated. If growth hormones act in a manner to divert nutrients from vegetative to reproductive buds as has been reported (Ross 1979) then in year two the tree might be over-compensating for this temporary diversion and act to reverse the process. This might explain the increased flowering of controls over treated trees. The effects could act differently for male and female and for early and late applications.

Table 3. Number of flowers per tree for each treatment after one, two and three years.

Growth substance	Conc. mg/l	Years after treatment	Number of Flowers Per Tree									
			Male					Female				
			July		August		Range	July		August		Range
			Mean	Range	Mean	Range		Mean	Range	Mean	Range	
Control	-	1	1.8	0-7	1.8	0-7	0-7	1.0	0-4	7.8	0-31	0-31
		2	56.2	3-111	107.5	20-218	33.5	1-102	56.8	1-215	0-5	0-5
		3	-*	-	-	-	2.8	0-6	2.0	0-5	0-5	0-5
GA4/7	200	1	7.2	1-16	2.2	0-9	27.8	0-67	0	-	-	-
		2	43.5	9-134	15.5	2-29	63.8	2-137	13.0	0-44	0-44	0-44
		3	-	-	-	-	4.0	0-12	0.8	0-3	0-3	0-3
GA4/7	800	1	118.2	0-261	0	-	27.8	0-79	0	0-1	0-1	0-1
		2	185.5	13-398	12.2	0-26	41.0	5-85	9.2	0-18	0-18	0-18
		3	-	-	-	-	8.8	0-32	0.8	0-3	0-3	0-3
GA4/7 GA ₉	200 10	1	22.5	3-74	2.8	0-7	2.0	0-4	0	-	-	-
		2	94.2	30-171	17.0	4-43	33.5	0-64	6.2	2-15	2-15	2-15
		3	-	-	-	-	0.0	-	1.2	0-3	0-3	0-3
GA4/7 NAA	200 100	1	43.8	2-88	47.2	0-155	8.0	0-20	2.5	0-10	0-10	0-10
		2	40.0	0-138	115.5	43-186	4.8	0-10	9.2	1-25	1-25	1-25
		3	-	-	-	-	6.2	0-9	3.0	0-10	0-10	0-10

*Numbers of male flowers were not determined in year three.

An alternative (and simpler) explanation is that in year one the environmental conditions were more conducive to flower initiation than in the subsequent two years.

Relationship Between Height and Flowering

Average height before and after treatment showed (after testing with Chi-square distribution) there to be no effects on leader growth during the second year. Inhibition of the terminal shoot was reported to occur in jack pine (Cecich 1983) but this was on young seedlings which were not of flowering age. Stimulation of vegetative growth has been reported to occur in loblolly pine (Hare 1979), and Ross (1983) working on Englemann spruce (P. englemannii Parry) indicated a close relationship between vegetative growth and level of GA4/7 applied. Height growth and not lateral growth was measured in this study. Therefore the possibility of more potential flowering sites could not be assessed.

There was a close relationship between height before and after spraying but no correlation between height and the number of flowers per tree (Table 4). There was a significant correlation, however, between the initial height of trees and flowering two years later. The effect disappeared by year three; but this could be attributed to very low levels of flowering in all trees in year three. This low correlation between height and flowering contrasts with results reported by Simpson and Powell (1981). Flowering was greater in year two both in terms of flowers per tree and numbers of trees flowering (Tables 3, 5). The significant correlation between height and flowering in year two could be due to the natural rhythms in cone production or it is possible that the

Table 4. Correlation coefficients of height before and after treatment, numbers of male and female flowers one and two years after treatment and female flowers three years after treatment.

	2	3	4	5	6	7
1	.940**	.018	.307	.491**	.440**	.185
2		.033	.301	.472**	.455**	.138
3			.431**	.430**	.188	.278
4				.531**	.544**	.723**
5					.476**	.532**
6						.224

**Significant at probability level 0.99.

- 1 - Height before treatment.
- 2 - Height after treatment.
- 3 - Number of male flowers one year after treatment.
- 4 - Number of female flowers one year after treatment.
- 5 - Number of male flowers two years after treatment.
- 6 - Number of female flowers two years after treatment.
- 7 - Number of female flowers three years after treatment.

Table 5. Percentage of controls and trees treated with gibberellin which produced flowers.

	Years after treatment	Percentage of trees flowering	
		Male	Female
Treated trees	1	68.8	40.6
	2	93.8	87.5
	3	-	40.6
Controls	1	12.5	12.5
	2	100.0	100.0
	3	-	75.0

effect of the treatments was to break a barrier to flowering allowing vigour associated with more rapid height growth to influence flowering levels. Since height was not related to flowering in the first year, it was assumed that flowering was due to treatments. Therefore, the increased flowering in the second year would reflect height more than hormone treatments. Possibly the effect of height growth is realized only when flowering reaches a certain level.

Levels of male and female flowering were closely related to each other in years one and two indicating that trees which flowered produced both sexes. Male flowering is often reported to be at lower levels than female but data are based on younger trees than used in this study (Ross 1979; Simpson and Powell 1981; Marquard and Hanover 1985; Ross et al. 1985). A close correlation between male and female flowering could have implications for seed orchard management. Given a low correlation and early rogueing on the basis of female flower production then trees which were low seed producers but high pollen producers would be lost.

Seed Quantity and Quality

Both seed quantity and quality were reduced in the year after treatment on treated trees (Table 6). Yields on trees treated with GA4/7 at 800 mg/l and GA4/7 + NAA were particularly low. In the second year yields were higher on trees receiving only GA4/7 and reduced on trees receiving GA4/7 + NAA. The data are based on few trees and tree to tree variation was large. No deterioration of seed quality after treatment was reported for western hemlock (Ross et al. 1981), Sitka spruce

Table 6. Seed yield (quantity and quality) in treated and untreated trees one and two years after treatments.

Hormone	Concentration	One Year After Treatment				Two Years After Treatments			
		No. of seeds per cone		Average cone wt.		No. of seeds per cone		Average cone wt.	
		Total	Filled	Viable	(g)	Total	Filled	Viable	(g)
Control		37.1*	30.3	29.6	1.96	31.4	25.0	22.4	1.60
GA ₄ /7	200 mg/l	46.5	24.5	23.6	1.36	43.0	26.4	25.1	1.62
GA ₄ /7	800 mg/l	38.8	24.3	17.2	2.60	45.4	36.4	36.3	2.14
GA ₄ /7	200 mg/l	-**	-	-	-	36.2	31.6	30.5	1.67
GA ₉	10 mg/l								
GA ₄ /7	200 mg/l	28.2	21.8	16.8	1.77	15.8	12.7	12.3	1.87
NAA	100 mg/l								
									1.15

*Data for controls, one year after treatment is from adjacent natural trees.

**No data available.

(Thompsett et al. 1980) or white spruce (Marquard and Hanover 1984b). However, Puritch et al. (1979) reported a reduction in filled seed per cone in Douglas-fir after GA4/7 promoted flowering. Overall seed yield, however, was increased because of the larger numbers of gibberellin-induced cones. In this study a reduction of about 20% in filled seed per cone (Table 6) was more than compensated by 28 times as many cone produced (Table 1). The data on seed yield are insufficient to determine if the reductions are a result of treatment or not. It is a subject which should be investigated, however, because of the indication that gibberellin-induced cones produce fewer viable seeds than 'natural' cones.

CONCLUSIONS

- (i) Both male and female flowering was promoted in terms of the number of flowers per tree and the proportion of trees producing flowers.
- (ii) Application of hormone in early July produced significantly more flowers than did application in early August. Use of GA4/7 + NAA promoted flowering when sprayed in August.
- (iii) Response was greater for male flowering than for female flowering.
- (iv) Female flowering was promoted at 200 and 800 mg/l of GA4/7 but male flowering was promoted only at 800 mg/l or when GA₉ or NAA was combined with 200 mg/l of GA4/7.
- (v) There are indications that the hormonal treatments have an effect two years after treatment. The effect is positive for female and negative for male flowering.

- (vi) The treatments did not affect terminal shoot growth and flowering levels were not related to tree height before or after treatment. Flowering two years after treatment was strongly correlated with height. Male and female flowering were also strongly correlated.
- (vii) Seed quality was reduced in the year following treatment but was little affected two years after treatment. The increased number of flowers induced by treatment more than compensated for reduced number of seeds.

REFERENCES

- Bonnet-Masimbert, M. 1982. Effect of growth regulators, girdling and mulching on flowering of young European and Japanese larches under field conditions. Can. J. For. Res. 12:270-279.
- Cecich, R.A. 1981. Applied gibberellin A4/7 increases ovulate strobili production in accelerated growth jack pine seedlings. Can. J. For. Res. 11:580-585.
- Cecich, R.A. 1983. Flowering in a jack pine seedling seed orchard increased by spraying with gibberellin A4/7. Can. J. For. Res. 13:1056-1062.
- Cecich, R.A. 1985. White spruce (Picea glauca) flowering in response to spray application of gibberellin A4/7. Can. J. For. Res. 15:170-174.
- Chalupka, W. 1984. Short note: Time of GA4/7 application may affect the sex of Scots pine flowers initiated. Silvae Genet. 3:173-174.
- Chalupka, W., M. Giertych and J. Kopcewicz. 1982. Effect of polythene covers, a flower inducing treatment, on the content of endogenous gibberellin-like substances in grafts of Norway spruce. Physiol. Plant. 54:79-82.
- Dunberg, A. 1974. Occurrence of gibberellin-like substances in Norway spruce (Picea abies (L.) Karst.) and their possible relation to growth and flowering. Studia Forestalia Suecica 111:1-62.
- Dunberg, A. 1980. Stimulation of flowering in Picea abies by gibberellins. Silvae Genet. 29:51-53.

- Greenwood, M.A. 1982. Rate, timing and mode of gibberellin application for female strobilus production by grafted loblolly pine. Can. J. For. Res. 12:998-1002.
- Hall, J. Peter. 1977. Effect of exogenous growth substances on flowering in grafted clones of Larix. Can. Dep. Fish. and Environ., Forest. Ser. Nfld. For. Res. Centre, Inform. Rep. N-X-151, 11 pp.
- Hall, J. Peter. 1981. Seed procurement in Newfoundland: Review and outlook. Env. Can., Can. Forest. Ser., Nfld. For. Res. Centre, Inform. Rep. N-X-204. 25 pp.
- Hare, R.C. 1984. Application, method and timing of gibberellin A4/7 treatments for increasing pollen cone bud production in southern pines. Can. J. For. Res. 14:128-131.
- Kamienska, A., R.P. Pharis, R.L. Wample, C.C. Kuo and R.C. Durley. 1973. Gibberellins in conifers. Proc. of 8th International Conference on Plant Growth Substances, Hirokawa Publ. Co., Tokyo, Japan, pp. 305-313.
- Kato, Y.M., I. Miyake and H. Ishikawa. 1958. Initiation of flower bud by gibberellin in Cryptomeria japonica. J. Jap. For. Soc. 49:405-408.
- Katsuta, M., M. Saito, C. Yamamota, T. Kaneko and M. Itoo. 1981. Effects of gibberellins on the promotion of strobilus production in Larix leptolepis Gord. and Abies homolepis Sieb. et Zuc. Bull. For. and For. Prod. Res. Inst. No. 313. pp. 37-45.

- Luukkanen, O. 1979. Hormonal treatment increases flowering of Norway spruce grafts grown in a plastic greenhouse. Foundation for Forest Tree Breeding, Helsinki, Finland, Ann. Rep. 1979, pp. 20-26.
- Luukkanen, O. 1980. Promotion of flowering in Scots Pine grafts by means of gibberellins. Proc. IUFRO Working Party S2.03.05 Symposium "Scots Pine Forestry of the Future", Kornik, Poland. 9 p.
- Luukkanen, O. and S. Johansson. 1980a. Flower induction by exogenous plant hormones in Scots Pine and Norway spruce grafts. Silv. Fenn. 14:95-105.
- Luukkanen, O. and S. Johansson. 1980b. Effect of exogenous gibberellins on flowering in Pinus sylvestris grafts. Physiol. Plant. 50:365-370.
- Marquard, R.D. and J.W. Hanover. 1984a. Sexual zonation in the crown of Picea glauca and the flowering response to exogenous GA4/7. Can. J. For. Res. 14:27-30.
- Marquard, R.D. and J.W. Hanover. 1984b. Relationship between gibberellin A4/7 concentration, time of treatment, and crown position on flowering of Picea glauca. Can. J. For. Res. 14:547-553.
- Marquard, R.D. and J.W. Hanover. 1985. Floral response of Picea glauca to gibberellin A4/7, naphthaleneacetic acid, root-pruning, and bien-nial treatment. Can. J. For. Res. 15:743-746.
- Morgenstern, E.K. and L.W. Carlson. 1979. Tree seed production and tree improvement in Canada - research and development needs 1977-1987. Environ. Can., Forest. Ser., Petawawa For. Exp. Stn., Inform. Rep. PS-X-74. 99 p + App.

- Pharis, R.P. 1979. Promotion of flowering in the Pinaceae by hormones - a reality. In Proc. 13th Lakes States Forest Tree Improvement Conf., August 17-18, U. Minnesota. pp. 1-10.
- Pharis, R.P. and S.D. Ross. 1976. Gibberellins: Their potential uses in Forestry. Outlook on Agriculture 9:2, pp. 82-87.
- Pharis, R.P. and S.D. Ross. 1984. Progress in hormonal cone induction in Pinaceae conifers. In Proc. of the 19th meeting of the Canadian Tree Improvement Association, Part 1. Ed. C.W. Yeatman, Petawawa Nat. Forest. Inst. Chalk R., Ont. pp. 163-169.
- Pharis, R.P., S.D. Ross and E. McMullan. 1980. Promotion of flowering in the Pinaceae by gibberellins. III. Seedlings of Douglas-Fir. *Physiol. Plant.* 50:119-126.
- Pharis, R.P., S.D. Ross, R.L. Wample and J.N. Owens. 1976. Promotion of flowering in conifers of the Pinaceae by certain of the gibberellins. *Acta Horticulturae* 56:155-162.
- Pharis, R.P., D. Tomchuk, F.D. Beall, R.M. Rauter and G. Kiss. 1986. Promotion of flowering in white spruce (Picea glauca) by gibberellin A4/7, auxin (Naphthaleneacetic acid), and the adjunct cultural treatments of girdling and CA (NO₃)₂ fertilization. *Can. J. For. Res.* 16:340-345.
- Philipson, J.J. 1985. The promotion of flowering in large field-grown Sitka spruce by girdling and stem injections of gibberellin A4/7. *Can. J. For. Res.* 15:166-170.

- Puritch, G.S., E.E. McMullan, M.D. Meagher and C.S. Simmons. 1979. Hormonal enhancement of cone production in Douglas fir grafts and seedlings. *Can. J. For. Res.* 9:193-200.
- Ross, S.D. 1976. Differential flowering responses by young Douglas fir grafts and equi-sized seedlings to gibberellins and auxin. *Acta Horticulturae.* 56:163-168.
- Ross, S.D. 1979. Early flower induction in Douglas fir. 1976. Trials at Sequim, Washington. I. Hormone treatments and application regimens. *For. Res. Tech. Rep.* 042-3201/79/45, Weyerhaeuser Company, Centralia, Washington. 15 p.
- Ross, S.D. 1983. Enhancement of shoot elongation in Douglas fir by gibberellin A4/7 and its relation to the hormonal promotion of flowering. *Can. J. For. Res.* 13:986-994.
- Ross, S.D., R.P. Pharis and J.C. Heaman. 1980. Promotion of cone and seed production in grafted and seedling Douglas fir seed orchards by application of gibberellin A4/7 mixture. *Can. J. For. Res.* 4:464-469.
- Ross, S.D., R.F. Piesch and F.T. Portlock. 1981. Promotion of cone and seed production in rooted ramets and seedlings of western hemlock by gibberellins and adjunct cultural treatments. *Can. J. For. Res.* 11:90-98.
- Ross, S.D., J.E. Webber, R.P. Pharis and J.N. Owens. 1985. Interaction between gibberellins A4/7 and root pruning on the reproductive and vegetative process in Douglas-fir. I. Effects on flowering. *Can. J. For. Res.* 15:341-347.

- Schmidtling, R.C. 1983. Genetic variation in fruitfulness in a loblolly pine (Pinus taeda L.) seed orchard. *Silvae Genet.* 32:76-80.
- Simpson, J.D. and G.R. Powell. 1981. Some factors influencing cone production on young black spruce in New Brunswick. *The Forest. Chron.* 57:267-269.
- Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics, McGraw-Hill Book Co. Inc. New York. 481 p.
- Thompsett, P.B, A.M. Fletcher and G.M. Arnold. 1980. Promotion of cone and seed production on Sitka spruce by gibberellin application. *Annals of Applied Biology Paper.* No. 123. 9 p.